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CLASSIFICATION

GROUP

CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

APPLICATION No. 897, 460

PRIORITY DATE

No. OF CLAIMS

LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

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In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 5 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 35 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential screw element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

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A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lover sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft 13.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein P_c is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in vell casing, the made-up tool is lowered into the vell as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the vell tubing is revolved. The friction member 42 engages with the vall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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- 1. A device for expanding a metallic liner inside a conduit which device comprises a shaft element, an expanding die member attached to said shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against said liner by a substantially constant force.
 - 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
 - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 4. The device of Claim 3 wherein said compression means comprises
 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a sleeve-like element connected to said movable bearing plate member and slidably positioned on said shaft and a member connected to said shaft to limit the travel of said sleeve-like element.
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft.
 - 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

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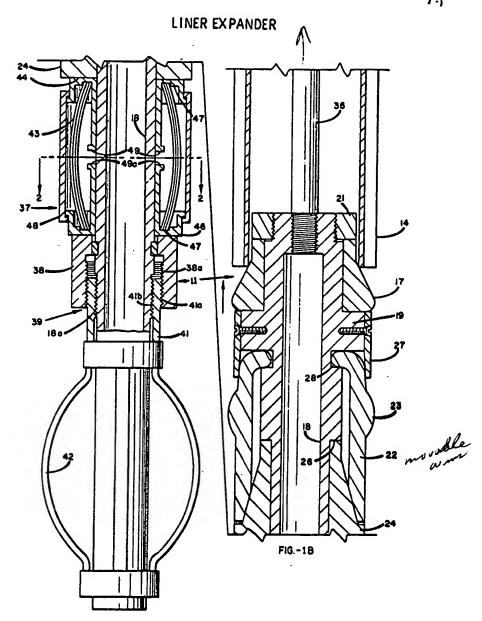
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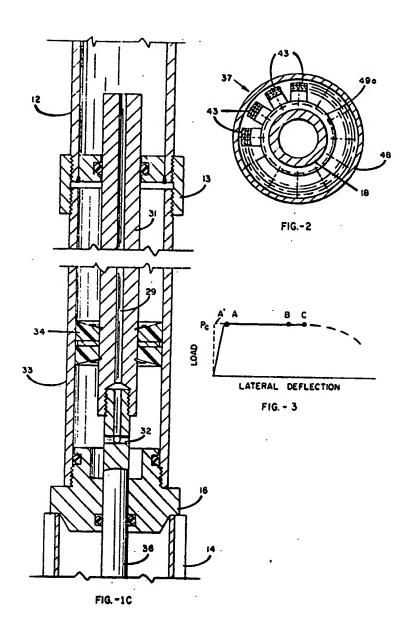
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3. Du device of Claim 2 wherein said constant force spring contercomprises a plantity of column disposed around which shaft, a first boaring
plate number and a second bearing plate moders, such of said boaring plate
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with said come number, stop more commerted to said staff to limit the axial
travel of said movefule boaring plate number along said shaft, and compression
means for waintaining a lateral defication in said columns.

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- 7. A device for installing at expended antallis lings in a commist which comprises a sylintrical short classical on expending the number mounted on mid shall, said his senter comprising a plannity of are spekara disposed circumfurentially around the outside of said shaft and being pivotable outearthy therefrom to contact the liner; a scaled asymming maker slidshly positioned on said short between said shaft and maid are ecology to arge said are markers outstandly from said shafts a plurality of slander columns, each bewing a long reutingular orces-section and disposed sireunferentially short said thaft; an upper bearing plate member and a lower bearing plate member, such sliderly positioned on said shaft and contacting opposite orde of said column; limiting slaws ubtacked to each of soid bearing plate numbers and although positioned as said statts a shoulder maket on such shalls a differential some charact economics will thousant and said she't to apply a bushing local to said enimum sold thoulear being consequents with the limiting sizews semmerted to emil lower bushing plate mester, whereby the aziel trevel of said bearing plate members is limited; said column resolute branchitting their buckling look to each arm numbers to urgs said arm spec enterrally with a substantially countral force.

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An object of the present invention is a device for applying a convisat force to an expending the or other similar apprecias so that a presquarted maximum force to meanted against a work place. Another object is an improved expending tool for installing metallic liners is a conduct, which expending tool our apply so greater them a predeterminal force to the liner heing installed in the constant. Still another object of the invention is an economical and easily followed constant force exciss device. A further object to a ranged, easy-to-overable expending tool contexts great a spring device. These and other objects of the invention will become apparent by reference to the full owing description of the invention.

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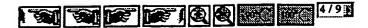
Figure 2 to a sectional where of the apparatus of Figure 1A tabes at

Figure 3 is a typical plot or applied load versus believiton for the constant force spring device of the Leventice.

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Exterring to the drawings, Figure 15 is the botton portion of a liner expending took for one in installing a metallic liner in a well, while Pigure 13 Libertrotes the middle section of such a total and Pigure 30 veyesseats the upper section of the tool. The expending tool il is attached to stantant well taking 15 by compling 15 and, typically, may be incorred from the surface through a well ensing (not shown) to a point in the seeing at which th in sazired to install a metallic liner. Before inserting the took into the well, an alongsted vartically amongsted liner is fabricated from mild stand, or ether suiteble mileshle meterial, is placed on the teol. The corrugated liner is occured in position by contact at its upper end with a cylindrical ther 16 and, at the lower and by contact with a first-stage expanding die 17 in the form of a transmist circular core which serves as a firststage expending die in the second bereinsfter described. The expending die is finally obtained to a centrally located, elemented symmetrical bollor shert ld which forms a portion of the body of the tool. As shows, the expending 61s 17 is half in place between a lower shoulder 19 and collar 21 threaded outs the short. . A plurality of moveple arms 27, preferably provided with outwardly sularged portions 25 mear the top, who disposed in the form of a sylindar around that's 16. The unlarged purbloss of the sens 23 upon being soved outvarily emissi the liner to perform the fixel step of expending the surregated ... o a substantially syllatrical shape. The are centers 22 ere pivotally ettiched to the shaft so as to be souble outsirally from the shaft by a tapared expending member 26 alidebly positioned on the sheft to serve as a second-stage olar. The seriess of the master St, as show, moves spendly along the chaft to sugges with the area and more than outserfly. Advantageously, the inside surfaces of the case 22 and the outside surface of expending member 24 ting sections, typically octogramal in shape. The oxyention of the exaers is controlled by the position of the master 20 raich moves specially

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In operation, the liner setting tool is assembled at the surface, so described shows, and a glass cloth saturated with a revisces material may be urapped around the corrugated tube to form the liner. The assembly is lovered into the wall at the location at which the liner is to be set. A liquid, such so oil, is then peoped under presence down the well tubing and flows through the percentage 29 provided he polithed not 31, through purts 52 and into exitader 35 commetted to the upper end of the shoulder 16. Upon the application of finid pronume to the oplimier, the piston 34 seconds to polimbel red 31 nows upwerely in sylinder 33. As shows, rot 36 consects polished rot 31 and shaft 15 spon eitich is mourtel the first-stage expending sie 17. Then the piston % moves upwortly through the splinder 33 the expending die 17 and the secondstage die 22 are drive apparelly into the corregated liner 18 and "iron out" the corregations in the liner, so that the expected liner may contact the incide well of the casing in which it is being installed. Positioned on the shaft below the expending menter th is a communit torce spring number 37 which in employed to trips the expending number against the explaining stars 22 with a substantially sensiant force. The force exarted against the are senders being substantially constant, the force transmitted through the are nectors to the listy and to the during will be substantially constant so that either skieling of the tool is the casing or recture of the caring is precluded. Of course, the time provided by the spring member is preselected so that the frictional



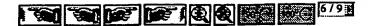
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forces between the tool sed the liner and the presence emerted against the coning are maintained at presentated afte levels. The constant force spring marker essures that the contact presence between the liner founding portion 25 of the sums 22 is great except to provide the Soriced deformation of the obsing, while preventing decays to the easing or to the tool.

The senstant force spring season 37 is alidebly sounted on the shaft a the expending classes th and a cylindrical inner shoulder rovided with threads his and hit on the origin and the inside, per with threads on the shaft and the shoulder. The two of Directs are source, such as square, mulified equare, or time threats, nd very high lands and differ in pitch so that shoulder 35 is seven specify on the shaft if when the shaft is revolved relative to thinkle Al. The shoulder 36 is secured to the shuft 15 by splines 45 so that it can alide longitudically, but it is not free to rotate on the shaft. Finally stimuled to the lower and of the thinkle is a friction member, such as how agaings 42, a hydrentically estuated friction pas, or other each device for frictionally tentage eldeth and oruppe of the banduit to occure the thinkle senant park to the shuft- Preferably, the direction of the shoulder sis, and the pinch, or less, of threads like is slightly greater than min 78s, with the pitch rotte being slose to unity. In this : clock-wise revolution of the shaft relative to the thinkle on sher 35 to advance upward aligntly and a compression load to exe urily on apring element 37 to terms buckling. For energia, one veriferantory differential survey was made up using five and one-helf thrinds/inch equare de on a chart approximately 1.7-inch contains dismeter and five and threers threads/lech equare threads on a shoulder approximately 2.5-dashes





Donatest force spring element 37 comprises estiman element 53, entertageously convincing of a plurality of alongsted columns disposed around shaft
18. Upper bearing plate senter 54 in its contact with the apper ands of the
solumns and is although positioned on what if to tremouts the force of the
solumn and is although against the bottom and of expenden senter 54. Lower
bearing plate member 16 contacts the lower ands of the columns and is moved
tearing plates shaft by lengthediest movement of lower shouldar 50 on a
result of revolving differential moves almost 39. Growes 37 are provided
in mash of the bearing plates, to form an upper race and a lower race, into
which the costs of the columns are inserted. These growes any be comped to
menture with the shape of the column much it sected. A cover 18 any be
employed to anolisis forwign matter from the spring mechanism sade to protect
the number.

A seems for limiting the deflection of the columns to required.

Although the column element functions in a builded condition, application of crossalive compressive lead thereto upula cause total failure or repture of the columns. Therefore, a pair of stops by each type are provided for this purpose. As shown, the stops are rigidly commerced to the bearing plates, and, in affort comprise upper and lower limiting almosts positioned on the shaft to alide longitudinally thereon. The code of the stops may nove toward, or smajers, each other as the load on the spring number vertes. Lower slaves by in prevented from moving dama by loader shoulder 56 accessored to the chart 18.

Resever, the spacing between the scale to much as to limit the longitudinal determination of the column almosts by. Written alternative mames for preventing damage to the column almosts by. Written alternative mames for preventing damage to the column almosts by also be employed. For example, yeas or rings accessed on this other may serve as stops, or the cover his provided of the settable commentations may be employed for this purpose to limit longitudinal and/or lateral derivaction of equipme.

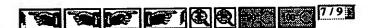
The columns of the column element 45 may be arranged exceed the start 16, which as shown here forces a portion of the body of the spring device, with sucks of the columns fitted in the recess \$7. The columns may be



fitted closely together as shown, or may be spaced around the race, with sope return used buttoon them to maintain the desired specing. The resident of mplayed will depend upon column abusemberistics and the enterists of construction. For example, the standardess reals of the column may be warred viduly, see the column axis say he round, flat, Marsi or hisged. The preferred stim is a this, elemen caluma with rounded smis, free to nove within mbers of the solumn ents. Saturdals which may be me my certain and low alloy stuple, onium statuless picole, various sepper burn allegs, such no, beryllium soppor, the high stokel alloys and other similar materials providing estimated weakenissi properties. Typically, the indisolutes are of long restampular cross-section, with the midth bring sees, and arranged so that the vider race of the univeris sormal to the dismeter of the sheft. Thus, with sufficient congression loading, the columns backle, and band short the axis having the loast somet of inertia, e.g., outrartly many from the shaft 18.

For example, a group of columns 0.168-inch thick by 0.438-inch wife by 10.626-inches long, with the anda youwish, were fabricated from A.I.S.I 4350 steel, quecabed and draws at 575°F. Back column was found to regular a 20 critical compression looking of \$50 pounds in order to buckle the animan. r bushing, the columns were found to have a very flot spring therectoristio, so shown in Figure 3, wherein Po is the critical beaking look and point exts the load and deflection at which the siress is the extreme fibers of the solute exceed the yield point of the untertal. Theoretically, the shape of this spring obtrasteristic surve is described by entre 04'AND. Actually, this curve is described by CARC due to friction in the system. Potote A and 3 sent typical straing limits, shich, of course, say he varied according to the application for which the spring to designed. For example, where a large number of flaming system are not ambicipated, a working atress just below the 30 Field point may be used, while with a great number of flanures, the working stress may be held to less them the endurance limit of the paterial of sometr tion. In the above-mentioned teate, the lateral deflection was limit

- 7 -





epproximately one fuch, at which the longitudinal difficultan was approximately 0.625 inches. From more deflection to the assumm deflection, the 450-pound loading was found to be substantially constant.

In eacher test a spring device was built, as deem, employing 80 columns, each having a critical buckling load of 1250 youds. The interest deflection was limited between 0 and about 3.00 inches by empropriately positioning the steps. One compressional loading, the spring element buckled at schematically 25,000 posses and from a longitudinal deflection of 0.04 inches (buckling) to stook 0.15 inches the load remained embermitally at 25,000

Of course, in derigating a spring element as above it in advantagements obtain the greatest possible value of longitudinal definations for specified values of laboral deflection and critical bushling load, while uninterlaing the attent level in the columns at a cafe level. The preferred columns, therefore, are landanted, as shown in Figures 12 and 2, with uninterlaint columns.

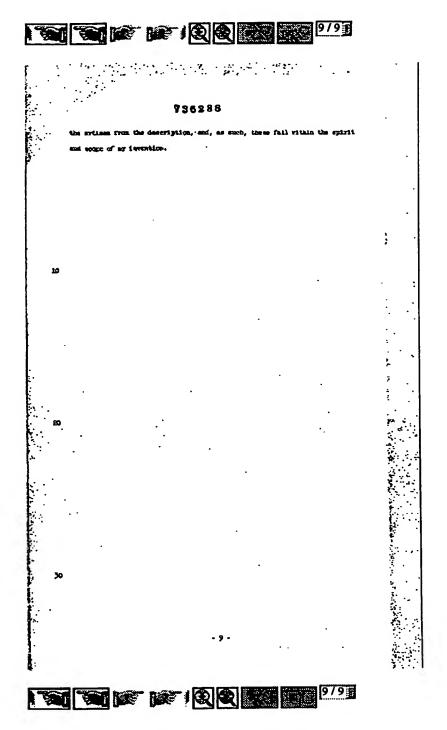
In the operation of the shows oxyselling tool for setting a limit in well making, the medo-up tool is lowered into the well as nestioned above, with the area 22 in the retreated position. Then the tool is at the hadred level, the sail totals is revolved. Too friction number by oxygen with the wall of the making one prevents thinkle it from revolving. But a several revolutions of the totals, lower churcher 30 is novel messaily by differential error 39 to bushle spring almost 37 which has a predefermined critical bushling load. This lead is transmitted spready signifies the lower set of expender 26, and its topered surface is engaged with the tapered surface on the incide of the oran 22 to argu the term outswelly with a constantially complete force proportional to the critical bushling load of the spring almost. Subsequently, the expending tool is passed through the liner to expend 10 in the caping in the secure described hereinhedore.

The foregoing description of a preferred substitute of my investigation has been given for the purpose of examplification. It will be understood that various mathifications in the details of construction will become apparent to

-8-

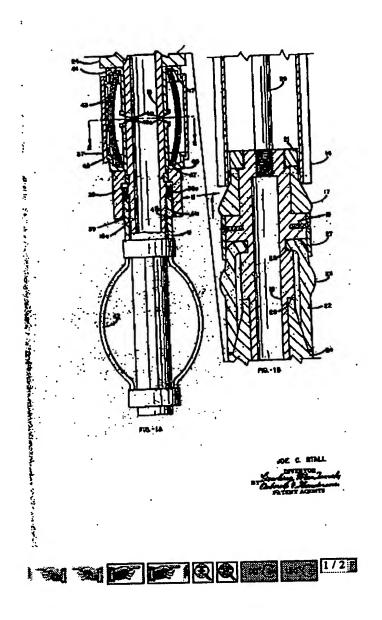
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